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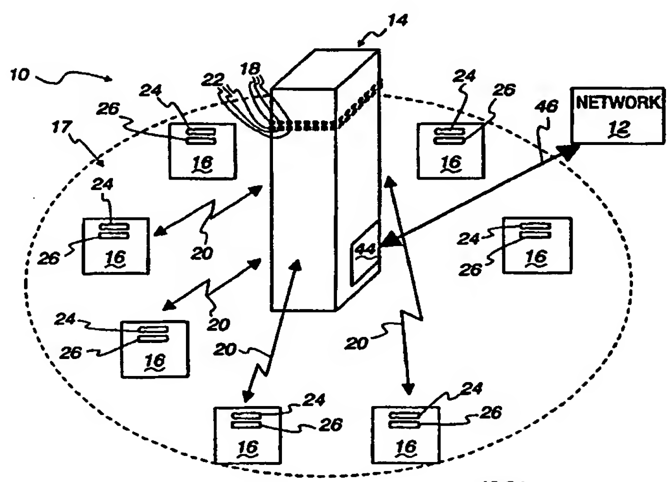

(57) Abstract

An optical communication system is provided for use with a communication network. The system includes a fixed site base station linkable to the communication network, and a plurality of fixed site subscriber units spaced from the base station. The base station includes a plurality of optical transmitters for transmitting communication signals through the atmosphere in the form of laser pulses, and a plurality of optical receivers for receiving communication signals through the atmosphere in the form of laser pulses. Each of the subscriber units includes an optical transmitter in optical alignment with one of the base station optical receivers for transmitting communication signals thereto through the atmosphere in the form of laser pulses, and an optical receiver in optical alignment with one of the base station optical transmitters for receiving communication signals therefrom through the atmosphere in the form of laser pulses. The laser pulses have wavelengths in the visible spectrum covering the wavelength range of 0.3 μm to 30.0 μm.

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OPTICAL COMMUNICATION SYSTEM AND METHOD

FIELD OF THE INVENTION

The present invention is directed towards communication systems, and more particularly, to so-called "wireless" communication systems.

BACKGROUND OF THE INVENTION

The ever increasing processing speed and popularity of computing systems, along with increasing population densities in urban areas, has created a need for communication systems capable of quickly transmitting ever-increasing amounts of data. Currently, demand has bypassed the bit rate capabilities of conventional telephone line technology, which is limited to less than 64,000 bits per second of data transmission. Other technologies with higher bit rate capabilities are known, but typically require either the laying of new cables, such as is required for coaxial cable systems or fiber optic systems, or the licensing of an electromagnetic spectrum, such as is required for wireless cellular systems and microwave link systems. These requirements may tend to decrease the commercial viability of such systems. Additionally, with the exception of fiber optic systems, many of the known technologies are limited to 40 million bits per second, or less, transmission rates whereas requirements for up to several billion bits per second of data transmission are anticipated.

The present invention is directed, at least in part, toward overcoming one or more of the problems discussed above.

SUMMARY OF THE INVENTION

In one aspect of the present invention, an optical communication system is provided for use with a communication network. The system includes a fixed site base station linkable to the communication network, and a plurality of fixed site subscriber units spaced from the base station. The base station includes a plurality of optical transmitters for transmitting communication signals through the atmosphere in the form of laser pulses, and a plurality of optical receivers for receiving communication signals through the atmosphere in the form of laser pulses. Each of the subscriber units includes an optical transmitter in optical alignment with one of the base station optical receivers for transmitting communication signals thereto through the atmosphere in the form of laser pulses, and an optical receiver in optical alignment with one of the base station optical transmitters for receiving communication signals therefrom through the atmosphere in the form of laser pulses. The laser pulses have wavelengths in the visible spectrum covering the wavelength range of 0.3μm to 30.0μm.

In another aspect of the invention, a communication system is provided that includes at least two fixed site communication units spaced from each other. Each

unit includes an optical transmitter and an optical receiver. The optical receiver of each unit is optically aligned with an optical transmitter of another unit for receiving communication signals through the atmosphere in the form of laser pulses transmitted from the optical transmitter of said another unit. The laser pulses have wavelengths in the visible spectrum covering the wavelength range of 0.3μm to 30.0μm.

In another aspect of the invention, at least one of the optical transmitters includes an active laser diode configured to convert electrical communication signals into the laser pulses.

In yet another aspect of the invention, at least one of the receivers includes a photovoltaic screen and a telescopic lens system for concentrating the laser pulses from at least one of the optical transmitters onto the photovoltaic screen.

In one aspect of the invention, at least one of the receivers includes an optical filter, an optical repeater, and a telescopic lens system for concentrating the laser pulses from at least one of the optical transmitters onto the optical filter.

In accordance with one aspect of the invention, a method of communicating is provided and includes the step of transmitting communication signals through the atmosphere in the form of laser pulses between a plurality of optical transmitters and optical receivers in a fixed site base station and a plurality of fixed site subscriber units which are spaced from the base station. Each of the subscriber units

includes an optical transmitter in optical alignment with one of the base station optical receivers and an optical receiver in optical alignment with one of the base station optical transmitters. The laser pulses have wavelengths in the visible spectrum covering the wavelength range of 0.3μm to 30.0μm.

In accordance with another aspect of the invention, a method of communicating is provided that includes the step of transmitting communication signals through the atmosphere in the form of laser pulses between an optical transmitter and optical receiver in a first communications unit and an optical transmitter and optical receiver in a second communications unit. Each of the optical receivers is in optical alignment with the optical transmitter of the other communications unit for receiving the communication signals transmitted from the optical transmitter. The laser pulses have wavelengths in the visible spectrum covering the wavelength range of 0.3μm to 30.0μm.

In one aspect of the invention, the transmitting step comprises the step of converting electrical communication signals into the laser pulses through an active laser diode.

In another aspect of the invention, the transmitting step comprises the step of concentrating the laser pulses through a telescopic lens system.

In yet another aspect of the invention, the transmitting step comprises the step of passing the laser pulses through an optical filter.

In one aspect of the invention, the method further includes the step of converting the laser pulses into electrical communication signals through a photovoltaic screen.

In another aspect of the invention, the method further includes the step of retransmitting the laser pulses through an optical repeater.

It is the principle object of the invention to provide a new and improved optical communication system and method.

It is another object of the invention to provide a communication system and method that does not require the laying of new transmission cables.

It is yet another object of the present invention to provide a communication system that is capable of several bidirectional billion bits per second transmission rates.

Numerous other features and advantages of the present invention will become readily apparent from the following detailed description of the invention, the accompanying figures, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic representation of an optical communication system embodying the present invention;

FIG. 2 is a diagrammatic representation of an optical transmitter for use in the system of Fig. 1;

FIG. 3 is a diagrammatic representation of an optical receiver for use in the system of Fig. 1; and

FIG. 4 is a diagrammatic representation of another optical receiver for use in the system of FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Although this invention is susceptible to embodiment in many different forms, the preferred embodiments of the invention are shown. It should be understood, however, that the present disclosure is to be considered as an exemplification of the principles of this invention and is not intended to limit the invention to the embodiments illustrated.

Fig. 1 illustrates an optical communication system 10 that is capable of several billion bits per second of transmission rates without requiring extensive laying of transmission lines or cables. The system 10 is linkable to communication network 12, such as a public switched telephone network, a private branch exchange, a public land mobile telecommunication system, a microcellular communication network, a universal mobile telecommunication system, a satellite communication system,

networked cellular telephone base station, or a plurality of networked optical communication systems 10.

The system 10 includes a fixed site base station 14 and a plurality of fixed site subscriber units 16 located within a service area 17. The base station 14 includes a plurality of optical transmitters 18 for transmitting communication signals through the atmosphere in the form of laser pulses 20, and a plurality of optical receivers 22 for receiving communication signals through the atmosphere in the form of laser pulses 20. Each of the subscriber units 16 includes an optical transmitter 24 in optical alignment with one of the base station optical receivers 22 for transmitting communication signals thereto through the atmosphere in the form of laser pulses 20, and an optical receiver 26 in optical alignment with one of the base station optical transmitters 18 for receiving communication signals therefrom through the atmosphere in the form of laser pulses 20.

As seen in Fig. 2, each of the transmitters 18, 24 includes an active or injection laser diode 30, or other similar device currently used in optical communications, for nano/peco second optical pulsing. The laser diode 30 converts electrical communication 31 signals into laser pulses. Such laser diodes 30 are conventionally used in fiber optic systems for generating low power optical laser pulses for transmission through an optical fiber. Many types of such laser diodes 30, or other

similar devices used in optical communications today, are well-known in the art and may be utilized to practice the invention. The laser diode 30 is optically aligned with its respective optical receiver 22, 26 for transmitting laser pulses 20 in the visible spectrum through the earth's atmosphere.

The laser pulses 20 have wavelengths in the visible spectrum from ultraviolet to infrared. Preferably, the laser pulses 20 have wavelengths in the visible spectrum within the wavelength range of 0.3μm to 30.0μm, and in the highly preferred embodiment, within the wavelength range of 0.4μm to 0.7μm. Further, the laser pulses 20 can be transmitted from the transmitters 18, 24 at any discrete frequency within the aforementioned wavelength ranges. Thus, the laser pulses 20 from a transmitter 18 to a receiver 22 of a subscriber unit 16 may have a wavelength of 0.3μm, while the laser pulses 20 from the transmitter 24 of the subscriber unit 16 to a receiver 22 of the base station 14 may have a wavelength of 10μm. Further, some or all of the transmitters 18, 24 may transmit monochromatic laser pulses 20 having a specific fixed frequency. Alternatively, some or all of the transmitters 18, 24 may use wavelength division multiplexing (WDM) where a multitude of light wavelengths can be used for the laser pulses 20.

Each of the optical receivers 22, 26 includes a laser sensitive photovoltaic screen or a semiconductor laser detector 32, as seen in Fig. 3, or an optical filter 34 and

optical repeater 35, as seen in Fig. 4. Because the laser pulses 20 are travelling through the atmosphere, which is not a bounded wave guide, some scattering of the laser pulses occurs and the laser intensity will decrease at a rate proportional to the square of the transmission distance between each transmitter 18, 24 and receiver 22, 26 pair. Accordingly, as seen in Figs. 3 and 4, each of the optical receivers 22, 26 further preferably includes a telescopic lens system or optical concentrator 36 for gathering and focusing the laser pulses 20 onto the photovoltaic screen 32 or the optical filter 34. The telescopic lens system 36 preferably includes a suitable micro controller or computer controlled focal point adjustment system 38 to maintain a proper focus and alignment of the laser pulses 20 onto the photovoltaic screen 32 or optical filter 34. The power of the transmitters 18, 24 and the magnification power of the optical concentrator 36 will vary depending on the transmission distance and the desired transmission rate.

As seen in Fig. 3, the photovoltaic screen 32 converts the laser pulses 20 into electrical communication signals 40 for continued transmission through the system 10. As seen in Fig. 4, after the laser pulses pass through the filter 34, the repeater 35 reconfigures the laser pulses 20 into optical communication signals 42 for continued transmission through the system 10. Because many types of photovoltaic screens 32, optical filters 34, optical repeaters 35, telescopic lens systems 36, and focal point

adjustment systems 38 are well-known in the art and may be utilized to practice the invention, a more detailed description of these components is not required.

As seen at 44 in Figs. 1-4, conventional communications circuitry may be provided to amplify, reshape, retime, recreate, multiplex, and/or demultiplex the communication signals 31, 40, 42 as they are transmitted to the laser diode 30 and transmitted from the photovoltaic screen 32 or optical repeater 35. Such circuitry is well-known in the art and further description is not required herein.

Returning to Fig. 1, a communications link 46 is provided between the network 12 and the base station 14. Preferably, the base station 14 is linked to the network 12 by a very high bandwidth or wavelength division multiplexed optical fiber cable, or through optical transmitters 18, 24 and receivers 22, 26 as described herein.

In operation, communication signals from the network 12 are transmitted through the link 46 to the base station 14 where they are demultiplexed and otherwise reconfigured before being fed to the respective transmitters 18 which will convert the communication signals 31 into the laser pulses 20 for downlinking to the subscriber units 16. Each of the subscriber units 16 will have its telescopic lens system 36 optically aligned and focused at one of the transmitters 18 for receiving the laser pulses 20 therefrom. Each subscriber unit 16 could be tuned to the same or different wavelengths. The photovoltaic screen 32 or optical filter 34 and repeater 35 will then

convert the laser pulses 20 into communication signals 40, 42 corresponding to the output received from the base station 14.

For the uplink from the subscriber units 16 to the base station 14, communication signals 31 are input into a subscriber unit 14 for conversion by the laser diode 30 of the transmitter 24 into laser pulses 20. One of the optical receivers 22 in the base station 14 will have its telescopic lens system 36 optically aligned and focused at the transmitter 24 for receiving the laser pulses 20 therefrom. The photovoltaic screen 32 or optical filter 34 and repeater 35 of the optical receiver 22 will then convert the laser pulses 20 into communication signals 40, 42 for continued transmission to the network 12 via the link 46 after passing through the circuitry 44. Alternatively, rather than passing to the network 12, signals intended for another subscriber unit 16 in the system 10 may be directly sent thereto by the base station 14 through local switching circuits in the base station 14. Preferably, the communication signals 40, 42 will be multiplexed and transmitted through a higher bandwidth system to the network 12, or to another subscriber unit 16. Preferably, the switching or connection between subscribers of different base station 14 is governed by a switching center in the network 12, while limited local switching function may be programmed into each base station 14 for connecting two subscriber units 16 within the same service area 17.

It should be understood that the bit rate in the uplink and/or downlink can be adjusted by adjusting the pulse width of the laser pulses 20 and by adjusting the power of the transmitters 18, 24. Further, the bit rate for the uplink may be different than the bit rate for the downlink, which is advantageous in a number of situations. For example, if a subscriber unit 16 is being utilized for "surfing" the internet, a very large bit rate may be provided for the downlink, without requiring an equally large bit rate for the uplink.

As previously noted, because the atmosphere is not about a wave guide, the signal strength of the laser pulses will decrease with distance. However, communication between distances at least on the order of 100s of meters would be sustainable between the base stations 14 and the subscriber units 16. Further, while the system 10 will not be as error-free as an optical fiber cable, a single bit simple error correction scheme can overcome most of the error situations.

It should also be understood that, while the system 10 is shown in the form of a hierarchal and centralized star network, other network topologies, including decentralized topologies, may also be used for the system 10. For example, the system 10 could be configured so that the laser pulses 20 are transmitted between a pair of subscriber units 16, or all of the subscriber units 16.

It should also be understood that a plurality of the systems 10 may be provided to cover a plurality of service areas 17, as is conventionally done in current wireless cellular systems and networks, such as a cellular style tree network.

It should be appreciated that the laser pulses in the visible spectrum can easily deliver several billion bits per second of data transmission. In this regard, it should be appreciated that the wide bandwidth of the laser pulses provides an opportunity for dynamic allocation within the bandwidth. Additionally, the bandwidth for the uplink from each subscriber unit 16 is independent of the bandwidth for the downlink to each subscriber unit 16. This allows for each of the uplink and downlink to be of gigabit bandwidth. Further, as previously noted, this allows for the bandwidth of the uplink to be different from the bandwidth of the downlink. Additionally, because the laser pulses 20 are a relatively focused transmission, issues of electromagnetic wave interference between subscriber units 16 are reduced or completely eliminated. In this regard, it should also be appreciated that other electromagnetic frequency radiation should not effect the system 10. Further, because of the fine tune focusing of the telescopic lens system 36, external visible spectrum light, such as general atmospheric light should not effect the system 10. Optical filters and/or waveform reshaping repeaters can also be used to prevent interference by screening out selected wavelengths of visible spectrum light.

It should further be appreciated that the system 10 does not require extensive laying of transmission cables between units, thereby avoiding not only the cost involved in laying such cables but also avoiding right-of-way concerns as to where the cables could be placed and time lost in establishing a communication system while waiting on such cables to be laid. Thus, not only are infrastructure costs minimized, but the system 10 of the present invention may be quickly established in new locations.

It should also be appreciated that laser pulses 20 such as used with the present invention can be narrowly focused with substantially all of the pulses transmitted directly at the receiver and without broad emanation of the signal as commonly found with radio signals. Accordingly, the energy of transmission may be substantially utilized (with little of the energy being wasted by being sent off in a wide range of directions). Moreover, it is significant that no license to use the laser pulses 20 of the present invention would be required, nor is there any likelihood that any would be required in the future. While licenses are required in the United States and many other countries to use radio signals in various ranges (in large part because of the limited number of such ranges available and the problem with interference between signals if no such control is exercised), the narrow focus of laser pulses eliminates interference between such pulses as a concern. Of course, the ability to operate systems 10 according to the present invention without licensing not only avoids the cost of such

licenses and the associated delays which could result in establishing the system 10 while awaiting such a license, but the lack of any limitations on use of the pulses in the identified range provide the potential for unlimited use of such systems 10.

Still other aspects, objects, and advantages of the present invention can be obtained from a study of the specification, the drawings, and the appended claims.

CLAIMS

I CLAIM:

1. An optical communication system for use with a communication network, the system comprising:

a fixed site base station linkable to the communication network, the base station including a plurality of optical transmitters for transmitting communication signals through the atmosphere in the form of base station laser pulses having wavelengths in the visible spectrum within the wavelength range of 0.3μm to 30.0μm, and a plurality of optical receivers for receiving communication signals through the atmosphere in the form of laser pulses; and

a plurality of fixed site subscriber units spaced from the base station, each unit including an optical transmitter in optical alignment with one of the base station optical receivers for transmitting communication signals thereto through the atmosphere in the form of subscriber unit laser pulses having wavelengths in the visible spectrum covering the wavelength range of 0.3μm to 30.0μm, and an optical receiver in optical alignment with one of the base station optical transmitters for receiving said base station laser pulses.

2. The communication system of claim 1 wherein at least one of the optical transmitters includes an active laser diode configured to convert electrical communication signals into the laser pulses.

3. The communication system of claim 1 wherein at least one of the optical transmitters includes a laser pulse generator.

4. The communication system of claim 1 wherein at least one of the receivers includes a laser detecting semiconducting device and a telescopic lens system for concentrating the laser pulses from at least one of the optical transmitters onto the laser detecting semiconducting device.

5. The communication system of claim 1 wherein at least one of the receivers includes a photovoltaic screen and a telescopic lens system for concentrating the laser pulses from at least one of the optical transmitters onto the photovoltaic screen.

6. The communication system of claim 1 wherein at least one of the receivers includes an optical filter, an optical repeater, and a telescopic lens system for

concentrating the laser pulses from at least one of the optical transmitters onto the optical filter.

7. A method of communicating comprising the step of transmitting communication signals through the atmosphere in the form of laser pulses between a plurality of optical transmitters and optical receivers in a fixed site base station and a plurality of fixed site subscriber units which are spaced from the base station and each of which includes an optical transmitter in optical alignment with one of the base station optical receivers and an optical receiver in optical alignment with one of the base station optical transmitters, the laser pulses having wavelengths in the visible spectrum within the wavelength range of 0.3μm to 30.0μm.

8. The method of claim 7 wherein the transmitting step comprises the step of converting electrical communication signals into the laser pulses through an active laser diode.

9. The method of claim 7 wherein the transmitting step comprises the step of concentrating the laser pulses in the optical receivers.

10. The method of claim 7 wherein the transmitting step comprises the step of passing the laser pulses through an optical filter.

11. The method of claim 7 further comprising the step of converting the laser pulses into electrical communication signals.

12. The method of claim 7 wherein the converting step comprises the step of screening out selected frequencies of visible spectrum light.

13. The method of claim 7 wherein the step of transmitting comprises the step of adjusting a data transmission rate of the communication signals by modifying at least one of a pulse width of the laser pulses and a power of the laser pulses.

14. The method of claim 7 wherein the step of transmitting includes the steps of:

transmitting communication signals at a first data transmission rate from at least one of the transmitters in the base station; and

transmitting communication signals at a second data transmission rate from at least one transmitter in the subscriber units, with the second data transmission rate being unequal to the first data transmission rate.

15. The method of claim 7 wherein the step of transmitting communication signals includes the steps of:

transmitting a communication signal in the form of a laser pulse from the transmitter in a first one of the subscriber units to one of the optical receivers in the base station; and

retransmitting the communication signal from one of the transmitters in the base station to an optical receiver in a second one of the subscriber units.

16. The method of claim 7 further comprising the step of retransmitting the laser pulses through an optical repeater.

17. A communication system comprising at least two fixed site communication units spaced from each other, each unit including an optical transmitter and an optical receiver, the optical receiver of each unit being optically aligned with an optical transmitter of another unit for receiving communication signals through the atmosphere in the form of laser pulses transmitted from the optical transmitter of said

another unit, the laser pulses having wavelengths in the visible spectrum in the wavelength range of 0.3μm to 30.0μm.

18. The communication system of claim 17 wherein at least one of the optical transmitters includes an active laser diode configured to convert electrical communication signals into the laser pulses.

19. The communication system of claim 17 wherein at least one of the receivers includes a photovoltaic screen and a telescopic lens system for concentrating the laser pulses from at least one of the optical transmitters onto the photovoltaic screen.

20. The communication system of claim 17 wherein at least one of the receivers includes an optical filter, an optical repeater, and a telescopic lens system for concentrating the laser pulses from at least one of the optical transmitters onto the optical filter.

21. A method of communicating comprising the step of transmitting communication signals through the atmosphere in the form of laser pulses between an

optical transmitter and an optical receiver in a first communications unit and an optical transmitter and optical receiver in a second communications unit that is spaced from the first communications unit, each of the optical receivers being optically aligned with the optical transmitter of the other unit for receiving the communication signals transmitted therefrom, the laser pulses having wavelengths in the visible spectrum within the wavelength range of 0.3μm to 30.0μm.

22. The method of claim 21 wherein the transmitting step comprises the step of converting electrical communication signals into the laser pulses through an active laser diode.

23. The method of claim 21 wherein the transmitting step comprises the step of concentrating the laser pulses through a telescopic lens system.

24. The method of claim 21 wherein the transmitting step comprises the step of passing the laser pulses through an optical filter.

25. The method of claim 21 further comprising the step of converting the laser pulses into electrical communication signals through a photovoltaic screen.

26. The method of claim 21 further comprising the step of retransmitting the laser pulses through an optical repeater.

27. The method of claim 21 wherein the transmitting step comprises the steps of:

transmitting communication signals at a first data transmission rate from the optical transmitter in the first communications unit; and

transmitting communication signals at a second data transmission rate from the optical transmitter in the second communications unit, with the second data transmission rate being unequal to the first data transmission rate.

28. An optical communication system for use with a communication network, the system comprising:

a fixed site base station linked to the communication network, the base station including a plurality of optical transmitters for transmitting communication

signals through the atmosphere in the form of laser pulses having wavelengths in the visible spectrum within the wavelength range of 0.3μm to 30.0μm; and

a plurality of fixed site subscriber units spaced from the base station, each unit including an optical receiver in optical alignment with one of the base station optical transmitters for receiving said laser pulses, and a transmitter linked with at least one of the communication network and the base station to provide a bidirectional communication link in combination with the laser pulses.

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Fig. 1

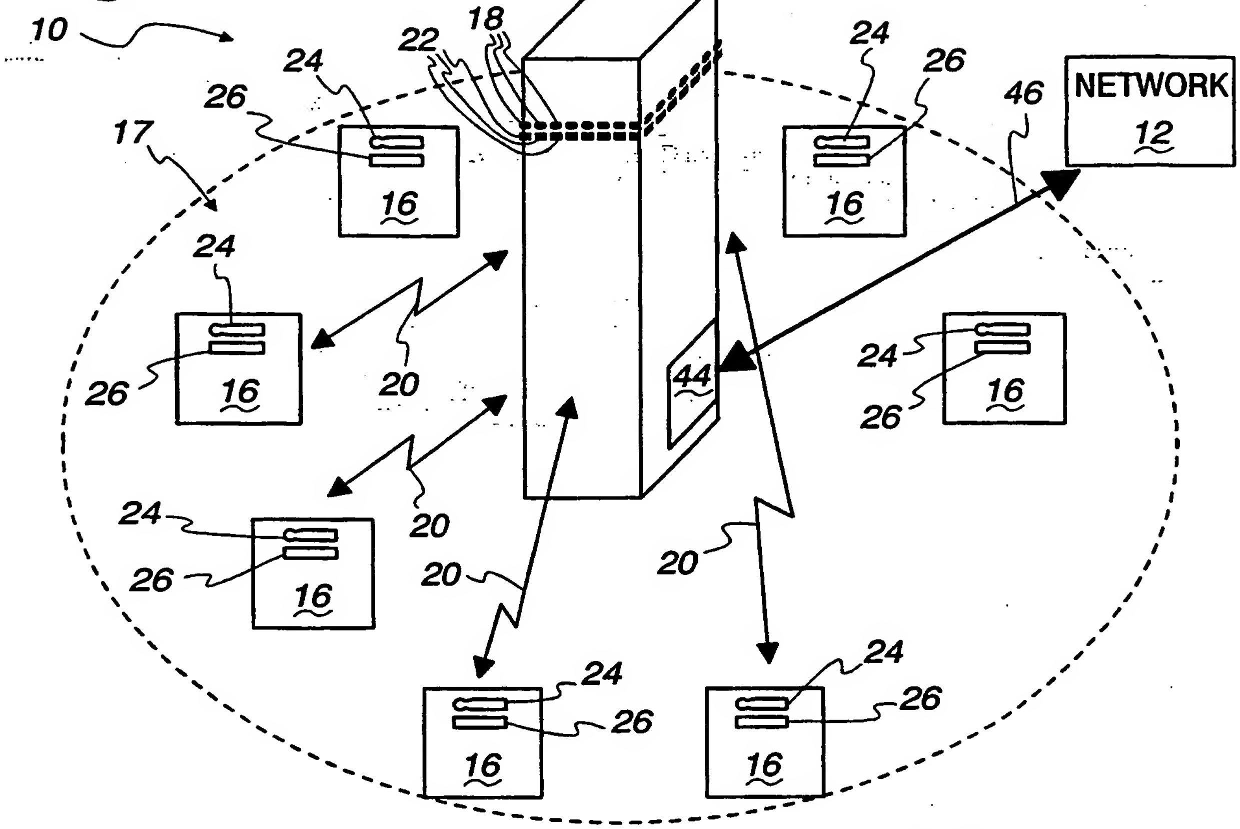


Fig. 2

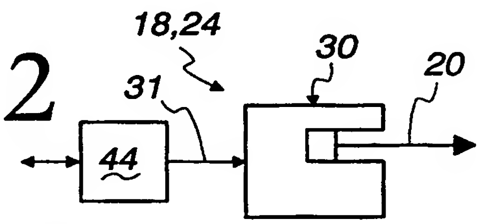


Fig. 3

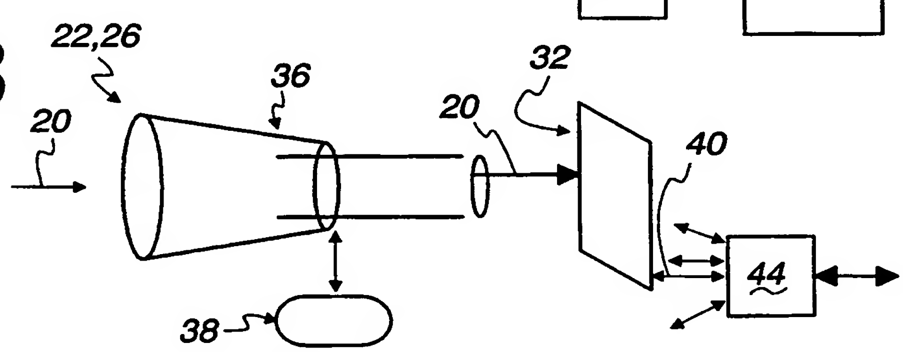
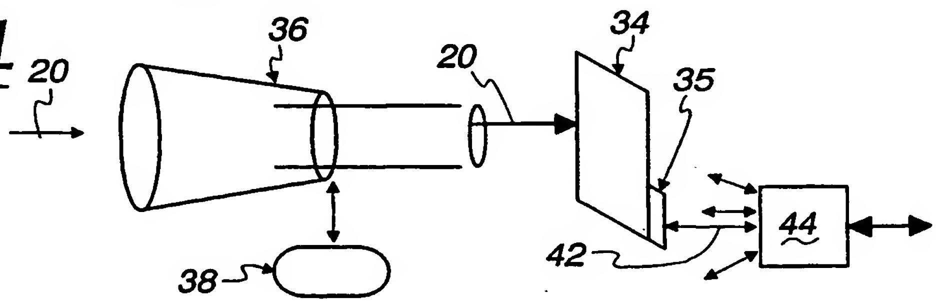


Fig. 4



INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/03960

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B10/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97 37445 A (DOMINION COMMUNICATIONS L L C) 9 October 1997 see abstract see page 2, line 16 - line 26 see page 4, line 5 - line 29	1-3, 7-12,28
Y	see page 6, line 37 - line 38 see page 9, line 1 - line 12 see page 10, line 2 - line 9 see page 19, line 8 - line 9 see page 22, line 1 - line 3	5,13,14, 23,24
A	see figures 1,4,6-9 ---	6,15,16, 20,26
A	PATENT ABSTRACTS OF JAPAN vol. 011, no. 320 (E-550), 17 October 1987 & JP 62 110340 A (NEC CORP), 21 May 1987 see abstract ---	1-3, 7-12,28

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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PCT/US 99/03960

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